ILLUMINANCE SELECTION

In 1979, the IESNA established an illuminance selection procedure, which was published in the 6th, 7th, and 8th editions of its Lighting Handbook. The philosophy of that procedure was to enable the lighting designer to select illuminances based on a knowledge of space and occupant characteristics as well as the task and worker characteristics.

The philosophy of that procedure has been embraced again in this edition, but the procedure has been modified and simplified to place visual performance and therefore illuminance selection more in balance with the other important lighting design criteria presented in this chapter and discussed throughout this edition of the IESNA Lighting Handbook. Specifically, the recommended illuminances provided in the Design Guide are based on the Society's judgment of best practice for "typical" applications. Every situation is unique so, naturally, typical conditions may not be appropriate for a specific application. As a professional, the lighting designer should have a better understanding of the particular space and the needs of the occupants and clients than what can be presented in a recommended illuminance value for a typical space.

Illuminance Recommendations

In 1979, the IESNA established nine illuminance categories, "A," the lowest set of recommended illuminances, through "I," the highest set. Each of the nine categories had general descriptions of the visual task, irrespective of the application. Generally, the same approach has been employed in this edition of the IESNA Lighting Handbook to help lighting designers establish the best task illumination. However, four important modifications have been adopted.

- The recommended illuminances are no longer provided without reference to a specific application. Every application in the Design Guide has a specific recommended illuminance (horizontal, vertical, or both) representing best practice for a typical application.
- The nine illuminance selection categories established earlier by the IESNA have been reduced to seven categories and organized into three sets of visual tasks (orientation and simple, common, and special). These groupings provide additional clarity to the category descriptions (Figure 10-9).
- Additional precision has been given to the task descriptions in each category. In the previous three editions it was impossible for the lighting designer to unambiguously ascertain what constituted, for example, "low contrast" or "small size." Specific

<table>
<thead>
<tr>
<th>A</th>
<th>Public spaces</th>
<th>30 lx (3 fc)</th>
</tr>
</thead>
<tbody>
<tr>
<td>B</td>
<td>Simple orientation for short visits</td>
<td>50 lx (5 fc)</td>
</tr>
<tr>
<td>C</td>
<td>Working spaces where simple visual tasks are performed</td>
<td>100 lx (10 fc)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>D</th>
<th>Performance of visual tasks of high contrast and large size</th>
<th>300 lx (30 fc)</th>
</tr>
</thead>
<tbody>
<tr>
<td>E</td>
<td>Performance of visual tasks of high contrast and small size, or visual tasks of low contrast and large size</td>
<td>500 lx (50 fc)</td>
</tr>
<tr>
<td>F</td>
<td>Performance of visual tasks of low contrast and small size</td>
<td>1000 lx (100 fc)</td>
</tr>
</tbody>
</table>

| G | Performance of visual tasks near threshold | 3000 to 10,000 lx (300 to 1000 fc) |

* Expected accuracy in illuminance calculations are given in Chapter 9, Lighting Calculations. To account for both uncertainty in photometric measurements and uncertainty in space reflections, measured illuminances should be within ±10% of the recommended value. It should be noted, however, that the final illuminance may deviate from these recommended values due to other lighting design criteria.

ranges of contrast and size have been established for this edition (Figures 10-10 and 10-11).

- Recommended illuminances increase roughly logarithmically with increasing task difficulty by combined changes in task contrast and task size, as defined in Figure 10-10. These recommendations are guided by both the scientific literature and practical experience.

High illuminances can partially compensate for small size and low contrast to maintain high levels of visual performance. Changes in visual performance as a function of task contrast and size, background reflectance, and observer age can be calculated precisely. For well-controlled situations, this procedure can be a useful predictive tool. However, performance at a visual task depends on many uncontrolled vi-
### Figure 10-9. Determination of Visual Task Parameters

**CONTRAST**

**How to calculate:**

\[ \frac{L_2 - L_1}{L_2} \text{ or } \frac{\rho_2 - \rho_1}{\rho_2} \]

where \( L \) is luminance (\( L_2 \) and \( L_1 \) must use same units),
\( \rho \) is reflectance,
\( b \) refers to the background, and
\( t \) refers to the target.

**Definition of contrast using reflectance requires equal illuminance on target and background.**

**How to interpret:**

- **Low contrast:** 0.3 or lower, but not near threshold
- **High contrast:** above 0.3

This division is based on the plateau-escarpment nature of visual performance. \(^{15,21}\)

**SIZE (see also Figure 10-11)**

**How to calculate:**

- **Solid angle (sr):**
  \[ \frac{(w \times h \times \cos \theta)}{d^2} \]
  where \( w \) and \( h \) are the dimensions (width and height) of the critical detail of the target,
  \( \theta \) is the viewing angle, and
  \( d \) is the viewing distance
  \( (w, h, \) and \( d \) must use the same units).

- **Visual angle (deg):**
  \[ \arctan \left( \frac{w \times \cos \theta}{d} \right) \]
  where \( w \) is the dimension (width) of the critical detail of the target,
  \( \theta \) is the viewing angle, and
  \( d \) is the viewing distance
  \( (w \) and \( d \)
  must use the same units).

**Note:** Visual performance for two different targets subtending the same area will be the same, even if the targets have different aspect ratios (e.g., a square-shaped target versus a long, rectangular-shaped target). \(^{15,21}\)

**How to interpret:**

- **Small size:** \( 4.0 \times 10^{-6} \text{sr} \) or smaller (solid angle), but not near the acuity limit
- **Large size:** larger than \( 4.0 \times 10^{-6} \text{sr} \)

This division, like that of contrast, is based on the plateau-escarpment nature of visual performance. \(^{15,21}\)

**Note:** \( \theta = 0.018 \text{ radians} = 60 \text{ min arc}; 1 \text{ sr} = 66^\circ \text{ visual angle} \) for a circular target. For a cone where \( \theta \) is the half-cone angle,
solid angle \( = 2\pi (1 - \cos \theta) \).

\(^*\) It should be noted that contrast threshold and the acuity limit are dependent on background luminance, duration of presentation, color, surround conditions, and in general, any number of factors that affect visibility, including those idiosyncratic to the viewer. Above a contrast of 0.3 and a size of \( 4.0 \times 10^{-6} \text{sr} \), these factors are not very important to visual performance.

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**Figure 10-10. Examples of Common Visual Angles and Solid Angles**

<table>
<thead>
<tr>
<th>Printed reading task from 19 in. (50 cm)</th>
<th>Visual angle (°)</th>
<th>Solid angle (sr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>6 point</td>
<td>0.03</td>
<td>( 1.7 \times 10^{-6} )</td>
</tr>
<tr>
<td>8 point</td>
<td>0.04</td>
<td>( 3.1 \times 10^{-6} )</td>
</tr>
<tr>
<td>10 point</td>
<td>0.05</td>
<td>( 4.8 \times 10^{-6} )</td>
</tr>
<tr>
<td>12 point</td>
<td>0.06</td>
<td>( 6.9 \times 10^{-6} )</td>
</tr>
<tr>
<td>14 point</td>
<td>0.07</td>
<td>( 9.4 \times 10^{-6} )</td>
</tr>
<tr>
<td>24 point</td>
<td>0.12</td>
<td>( 2.8 \times 10^{-5} )</td>
</tr>
<tr>
<td>36 point</td>
<td>0.18</td>
<td>( 6.2 \times 10^{-5} )</td>
</tr>
</tbody>
</table>

**Viewing a square-shaped object from 100 ft (30 m)**

<table>
<thead>
<tr>
<th>Object size</th>
<th>Visual angle (°)</th>
<th>Solid angle (sr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 x 3 in. (7.5 x 7.5 cm)</td>
<td>0.14</td>
<td>( 6.3 \times 10^{-5} )</td>
</tr>
<tr>
<td>6 x 6 in. (15 x 15 cm)</td>
<td>0.29</td>
<td>( 2.5 \times 10^{-5} )</td>
</tr>
<tr>
<td>12 x 12 in. (30 x 30 cm)</td>
<td>0.57</td>
<td>( 1.0 \times 10^{-4} )</td>
</tr>
</tbody>
</table>

**Wire sizes (diameter in cross section) viewed from 15 in. (40 cm)**

<table>
<thead>
<tr>
<th>Wire size</th>
<th>Visual angle (°)</th>
<th>Solid angle (sr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>American Wire Gauge (AWG) 30 (0.25 mm diameter)</td>
<td>0.04</td>
<td>( 3.4 \times 10^{-7} )</td>
</tr>
<tr>
<td>AWG 24 (0.51 mm diameter)</td>
<td>0.07</td>
<td>( 1.4 \times 10^{-6} )</td>
</tr>
<tr>
<td>AWG 20 (0.81 mm diameter)</td>
<td>0.12</td>
<td>( 3.5 \times 10^{-6} )</td>
</tr>
<tr>
<td>AWG 16 (1.29 mm diameter)</td>
<td>0.19</td>
<td>( 9.0 \times 10^{-6} )</td>
</tr>
<tr>
<td>AWG 12 (2.05 mm diameter)</td>
<td>0.31</td>
<td>( 2.3 \times 10^{-5} )</td>
</tr>
<tr>
<td>AWG 8 (3.28 mm diameter)</td>
<td>0.49</td>
<td>( 5.8 \times 10^{-5} )</td>
</tr>
</tbody>
</table>

**Circular drilled holes viewed from 15 in. (40 cm)**

<table>
<thead>
<tr>
<th>Hole diameter</th>
<th>Visual angle (°)</th>
<th>Solid angle (sr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.01 in. (0.25 mm)</td>
<td>0.04</td>
<td>( 3.4 \times 10^{-7} )</td>
</tr>
<tr>
<td>0.02 in. (0.51 mm)</td>
<td>0.07</td>
<td>( 1.4 \times 10^{-6} )</td>
</tr>
<tr>
<td>0.03 in. (0.76 mm)</td>
<td>0.11</td>
<td>( 3.1 \times 10^{-6} )</td>
</tr>
<tr>
<td>0.04 in. (1.02 mm)</td>
<td>0.15</td>
<td>( 5.6 \times 10^{-6} )</td>
</tr>
</tbody>
</table>

\(^*\) Angular width of single character stroke (vertical stroke, Times typeface).
\(^\dagger\) Average solid angle of total printed area of character for numerical digits (see reference 15).

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**The Basis for Deviating from the Recommended Illuminances**

Every visual task identified in the Design Guide has provisions for horizontal and vertical illuminance recommendations. Depending on the task, one or both illuminance recommendations are provided. Occasionally, the Guide refers the reader to an application chapter for recommended illuminances. The recommended values throughout the Design Guide represent consensus values formally obtained by the appropriate application committee.

Occasionally the visual task in a specific space is not typical, and Figures 10-10 and 10-11 should be used to adjust

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visual and nonvisual factors that are highly variable and largely indeterminable by the lighting designer. For example, it is often difficult or impossible to know the age, retinal health, and optical refraction of the worker. Moreover, worker motivation, education, manual dexterity, posture, stature, and level of fatigue are highly variable and usually unmeasurable. Therefore, a precise calculation method for visual performance cannot be justified for typical areas or activities. For this reason, the IESNA currently believes that the recommended illuminances in the Design Guide and in

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Figure 10-9 are adequate and appropriate guidelines for lighting design.
the illuminance for that task. Indeed, it is extremely important that the lighting designer have a clear understanding of the visual task being illuminated and then determine whether, in fact, the recommended illuminance is appropriate. It is also possible that more than one visual task is performed in a space. The lighting designer should make provisions to illuminate these tasks to the recommended levels unless other design criteria supercede illuminance as a design criterion.

The IESNA recognizes that illuminance is not the sole lighting design criterion. Other criteria in the design guide may be more important than illuminance; to address the primary design criteria, the lighting designer can deviate from the recommended illuminance. Further, and as listed in the section “How to Use the IESNA Lighting Design Guide” above, there are many other factors that might lead to deviation from the recommendations made in the Design Guide. Given the complexity and diversity of design goals for a specific application, it is impossible to formulate a formal, precise method for deviating from the recommended illuminances in the Design Guide. However, some guidance, based on descriptive statistics, is offered by the IESNA with regard to what might be considered “dramatic” deviations from a recommended illuminance.

Consider a hypothetical example. A survey of task illuminances was obtained for a large sample of open-plan offices where the primary visual task is reading 8- and 10-point print, and the recommended illuminance is 300 lx. Figure 10-12 illustrates the results of the survey. Illuminances ranged from 150 lx to 450 lx with a peak frequency of 300 lx. Roughly two-thirds of the illuminances (i.e., one standard deviation) were between 250 and 350 lx, and approximately 95% (i.e., two standard deviations) of the illuminances were between 200 and 400 lx. Dramatic deviations were those illuminances below 200 or above 400 lx and, in total, represented less than 5% of all illuminances surveyed.

In general, the IESNA believes that a dramatic difference between an actual and a recommended illuminance (i.e., a difference of two standard deviations or more) would be 1/3 more or 1/3 less than the recommended value. It should be noted again that an experienced lighting designer can produce a satisfactory illuminance outside this range, but it would be an exceptional achievement. As already noted above, the IESNA believes that any dramatic deviations from the recommended value should be carefully documented by the lighting designer, not only because documentation is good professional practice, but it is also good to have in case the design illuminance is ever challenged.

**Age**

Finally it should be noted that the recommendations for illuminances provided in the Design Guide are not made with respect to the age of the occupants. Generally, the visual requirements of older persons are significantly different from those of younger persons in the two ways: 1) there is a thickening of the yellow crystalline lens, which decreases the amount of light reaching the retina, increases scatter within the eye, and reduces the range of distances that can be properly focused (presbyopia); and 2) there is a reduction of pupil size, decreasing the amount of light reaching the retina.

The retinal illuminance of a typical 60-year-old person is only about one-third of the retinal illuminance of a typical 20-year-old person due to smaller pupil sizes and thicker lenses (Figure 10-13). Additionally, the near point of a typical 20-year-old person is 10 cm (4 in.), compared to more than 1 m (3 ft) for a typical 60-year-old person (Figure 10-
10-16 QUALITY OF THE VISUAL ENVIRONMENT

Figure 10-14. The decrease of the amplitude of accommodation with age.

14). Consequently, older persons tend to require higher task illuminances for the same retinal illuminances and, because of reduced clarity in the lens, have reduced image quality. Similarly, greater attention to sources of glare within the field of view is more important for older than for younger persons.

The population of persons older than 60 years is growing, and this means that the lighting specifier must consider the possibility of increasing the recommended illuminances and take measures to avoid glare and excessive luminance ratios in the field of view (see the sections “Direct Glare” and “Reflected Glare” above for additional information about glare). It should be noted too that after age 65, neurological factors (e.g., macular degeneration, diabetic retinopathy) become increasingly problematic. These changes demand even more sophisticated lighting design. It is recommended that other resources be consulted for guidance on the effects of age on the quantity and quality of illumination, and that this information, like that for other lighting design criteria, be factored into the final design.19-21

REFERENCES